United States Environmental Protection Agency
Solid Waste and Emergency Response (5305W)
EPA530-D-98-001A
July 1998
www.epa.gov/osw

Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities

Volume One

Peer Review Draft

DISCLAIMER

This document provides guidance to U.S. EPA Regions and States on how best to implement RCRA and U.S. EPA's regulations to facilitate permitting decisions for hazardous waste combustion facilities. It also provides guidance to the public and to the regulated community on how U.S. EPA intends to exercise its discretion in implementing its regulations. The document does not substitute for U.S. EPA's regulations, nor is it a regulation itself. Thus, it cannot impose legally-binding requirements on U.S. EPA, States, or the regulated community. It may not apply to a particular situation based upon the circumstances. U.S. EPA may change this guidance in the future, as appropriate.

ACKNOWLEDGMENTS

Jeff Yurk (U.S. EPA Region 6) and David Weeks (formerly of U.S. EPA Region 6), the primary authors/editors of this document, would like to acknowledge that the development of this document could not have been accomplished without the support, input, and work of a multitude of U.S. EPA and support contractor personnel. The foundation for the procedures and methodologies outlined in this document were first developed by the Office of Research and Development (ORD) and the Office of Solid Waste (OSW) in previous versions of combustion risk assessment guidance. The State of North Carolinas' combustion risk assessment methodology was also evaluated in preparation of this document. This version of the guidance was originally initiated in response to the desire of the Region 6 Multimedia Planning and Permitting Division to implement an up-to-date and technically sound hazardous waste combustion permitting program. The decision to incorporate guidance on a full range of national combustion risk assessment issues into the document was encouraged and supported by the Director of the Office of Solid Waste.

The development of this document was significantly enhanced by a number of capable organizations and personnel within U.S. EPA. Karen Pollard, Alexander McBride and David Layland of the Economic Methods and Risk Analysis Division in conjunction with Rosemary Workman of the Permits and State Programs Division and Karen Kraus of the Office of General Council provided overall policy, technical and legal comment on this document. David Reisman, Glenn Rice, Eletha Brady Roberts and Matthew Lorber of the National Center for Environmental Assessment (NCEA), Office of Research and Development and Dr. Dorothy Canter, Science Advisor to the Assistant Administrator for the Office of Solid Waste and Emergency Response, provided key input on breaking scientific developments in the areas of mercury speciation, the dioxin reassessment, endocrine disruptors, toxicity factors, sulfur and brominated dioxin analogs, as well as technical comment on the overall methodologies presented in the document.

Contributions by Dr. Larry Johnson of the National Exposure Research Laboratory of ORD and Jeff Ryan of the National Risk Management Research Laboratory of ORD were significant in providing methodologies for conducting TO analysis and defining appropriate detection limits to be used in the risk assessment. Donna Schwede of the National Exposure Research Laboratory of ORD and Jawad Touma of the Office of Air Quality Planning and Standards provided technical review comments to strengthen the air modeling section of the document. Review and comment on the soil and water fate and transport models was provided by Robert Ambrose of EPA's Environmental Research Laboratory in Athens, GA.

All U.S. EPA Regional Offices contributed valuable comments which have significantly improved the usability of this document. In particular, Region 4 aided in making sure guidance for conducting trial burns was consistent with this document, and Region 10 provided significant input on the subject of acute risk assessment and PCB analysis. The authors would be remiss if they did not acknowledge significant contributions from the Texas Natural Resource and Conservation Commission through both comments and discussions of real-world applications of risk assessment methodologies. Additionally, useful comments were received from the States of Colorado, Utah, and Alabama. The Region 6 Superfund Division is to be commended for its valuable review of the early document. Region 6 apologizes and bears full responsibility for any mistakes made in the incorporation of comment and input from all reviewers into the document.

Finally, this work could not have been completed without the tireless efforts of support contractor personnel. Tetra Tech EM Inc. (Tetra Tech), performed the bulk of the background research. The Air Group, under subcontract to Tetra Tech, helped develop the chapter on air dispersion modeling. The work of these contractors was performed under the technical direction of staff from the Region 6 Center for Combustion Science and Engineering, as well as key Agency project and contracting officers.

Region 6 looks forward to the insight and input yet to be provided by industry and other interested parties during the full external peer review of the document.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

Chapter **Page**

CONTENTS (Continued)

Chapter **Page**

CONTENTS (Continued)

CONTENTS (Continued)

Chapter **Page**

CONTENTS (Continued)

Chapter **Page**

Appendix

FIGURES

TABLES

LIST OF ACRONYMS

μg	Microgram
μm	Micrometer
ACGIH	American Conference of Governmental Industrial Hygienists
ADD	Average daily dose
AEFA	Average Emission Factor Approach
Ah	Aryl hydrocarbon
AHH	Aryl hydrocarbon hydroxylase
AIEC	Acute inhalation exposure criteria
AIHA	American Industrial Hygiene Association
APCS	Air pollution control system
ASTM	American Society for Testing and Materials
atm	Atmosphere
ATSDR	Agency for Toxic Substances and Disease Registry
AWFCO	Automatic waste feed cutoff
BaP	Benzo(a)pyrene
BAF	Bioaccumulation factor
BBS	Bulletin board service
BCF	Bioconcentration factor
BEHP	Bis(2-ethylhexyl) phthalate
BIF	Boiler and industrial furnace
BPIP	Building profile input program check
BSAF	Sediment bioaccumulation factor
Btu	British thermal unit
BW	Body weight
CAA	Clean Air Act
CARB	California Air Resources Board
CAS	Chemical Abstracts Service
CFR	Code of Federal Regulations
CKD	Cement kiln dust
CLP	Contract Laboratory Program
cm	Centimeters
COPC	Compound of potential concern
CRQL	Contract required quantitation limit
CSV	Unspeciated chromatographical semivolatiles
CWA	Clean Water Act
DEHP	Diethylhexylphthalate
dL	Decaliter
DNA	Dioxyribonucleic acid
DNOP	Di(n)octyl phthalate
DOE	Department of Energy
DRE	Destruction and removal efficiency

LIST OF ACRONYMS (Continued)

DW	Dry weight of soil or plant/animal tissue
EPACA	U.S. Environmental Protection Agency Correlation Approach
EQL	Estimated quantitation limit
ESP	Electrostatic precipitator
ExInter	Expert Interface Version 1.0
FW	Fresh weight (or whole/wet weight) of plant or animal tissue
g	Grams
GC	Gas chromatography
GEP	Good engineering practice
GRAV	Unspeciated gravimetric compounds
HEAST	Health Effects Assessment Summary Tables
HI	Hazard index
HQ	Hazard quotient
IARC	International Agency for Research on Cancer
IDL	Instrument detection limit
IEU/BK	Integrated exposure uptake/biokinetic
IPM	Insoluble polystryene microspheres
IRIS	Integrated Risk Information System
ISCSTDFT	Industrial Source Complex Short Term Draft
ISCST3	Industrial Source Complex Short Term 3
K	Kelvin
kg	Kilogram
LADD	Lifetime average daily dose
L	Liter
lb	Pound
LCD	Local climatological data annual summary with comparative data
m	Meters
MACT	Maximum achievable control technology
MDL	Method detection limit
MEHP	Monoethylhexyl phthalate
mg	Milligram
Mg	Megagram
MIR	Maximum individual risk
MJ	Megajoule
mL	Milliliter
MPRM	Meteorological processor for regulatory models

LIST OF ACRONYMS (Continued)

MPTER	Air quality model for multiple point source gaussian dispersion algorithm with terrain adjustments
MRL	Minimum risk level
NCDC	National Climatic Data Center
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRC	Nuclear Regulatory Commission
NTP	National Toxicology Program
NWS	National Weather Service
OAQPS	Office of Air Quality Planning and Standards
ORD	Office of Research and Development
OSHA	U.S. Occupational Safety and Health Administration
OSW	Office of Solid Waste
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo(p)dioxin
PCDF	Polychlorinated dibenzofuran
PCRAMMET	Personal computer version of the meteorological preprocessor for the old RAM program
PDF	Probability density function
pg	Picogram
PIC	Product of incomplete combustion
PM	Particulate matter
PMD	Portable monitoring device
PM10	Particulate matter less than 10 micrometers in diameter
POHC	Principal organic hazardous constituent
ppb	Parts per billion
ppm	Parts per million
ppmv	Parts per million by volume
ppt	Parts per trillion
PQL	Practicle quantitation limit
PU	Polyurethane
QA	Quality assurance
QAPjP	Quality assurance project plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RfC	Reference concentration
RfD	Reference dose

LIST OF ACRONYMS (Continued)

RME	Reasonable maximum exposure
RPF	Relative potency factor
RTDM	Rough terrain diffusion model
RTDMDEP	Rough terrain diffusion model deposition
s	Second
SAMSON	Solar and Meterological Surface Observational Network
SCRAM	Support Center for Regulatory Air Models
SF	Slope factor
SLERA	Screening level ecological risk assessment
SOCMI	Synthetic Organic Chemical Manufacturing Industries
SQL	Sample quantitation limit
SRA	Screening ranges approach
SVOC	Semivolatile organic compound
SW-846	U.S. Environmental Protection Agency Test Methods for Evaluating Solid Waste
TCDD	Tetrachlorodibenzo(p)dioxin
TDA	Toluenediamine
TDI	Toluene diisocyanate
TEF	Toxicity equivalent factor
TEQ	Toxicity equivalent quotient
TG	Terrain grid
TIC	Tentatively identified compound
TLV	Threshold limit value
TOC	Total organic carbon
TSD	Treatment, storage, and disposal
TTN	Technology transfer network
TWA	Time-weighted average
U/BK	Uptake/biokinetic
USCA	Unit-Specific Correlation Approach
USDA	U.S. Department of Agriculture
U.S. EPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USLE	Universal soil loss equation
UTM	Universal transverse mercator
VOC	Volatile organic compound

LIST OF VARIABLES

β_0, β_1	=	Regression constants (unitless)
γ	=	Empirical constant (unitless)
λ_z	=	Dimensionless viscous sublayer thickness (unitless)
μ_a	=	Viscosity of air (g/cm-s)
μ_w	=	Viscosity of water corresponding to water temperature (g/cm-s)
ρ_a	=	Density of air (g/cm^3 or g/m^3)
ρ_{forage}	=	Density of forage (g/cm^3)
ρ_s	=	Bed sediment density (kg/L)
ρ_w	=	Density of water corresponding to water temperature (g/cm^3)
θ	=	Temperature correction factor (unitless)
θ_{bs}	=	Bed sediment porosity (unitless)
θ_{sw}	=	Soil volumetric water content (mL water/cm^3 soil)
a	=	Empirical intercept coefficient (unitless)
A	=	Surface area of contaminated area (m^2)
A_{beef}	=	Concentration of COPC in beef (mg COPC/kg FW tissue)
$A_{chicken}$	=	Concentration of COPC in chicken meat (mg COPC/kg FW tissue)
ADD	=	Average daily dose (mg COPC/kg BW-day)
ADD_{infant}	=	Average daily dose for infant exposed to contaminated breast milk (pg COPC/kg BW infant/day)
ADD_{mat}	=	Average daily dose (mother) (pg COPC/kg BW mother/day)
AEF	=	Applicable average emission factor for the equipment type (kg/hr-source)
A_{egg}	=	Concentration of COPC in eggs (mg COPC/kg FW tissue)
Ah	=	Area planted (m^2)
Ahi	=	Area planted to *i*th crop (m^2)
A_I	=	Impervious watershed area receiving COPC deposition (m^2)
A_L	=	Total watershed area receiving COPC deposition (m^2)
A_{milk}	=	Concentration of COPC in milk (mg COPC/kg FW tissue)
A_{pork}	=	Concentration of COPC in pork (mg COPC/kg FW tissue)
AT	=	Averaging time (days)
A_W	=	Water body surface area (m^2)
b	=	Empirical slope coefficient (unitless)
Ba_{beef}	=	Biotransfer factor for beef (day/kg FW tissue)
$Ba_{chicken}$	=	Biotransfer factor for chicken (day/kg FW tissue)
Ba_{eggs}	=	Biotransfer factor for eggs (day/kg FW tissue)
BAF_{fish}	=	Bioaccumulation factor for fish (L/kg FW tissue)
Ba_{milk}	=	Biotransfer factor for milk (day/kg FW tissue)
Ba_{pork}	=	Biotransfer factor for pork (day/kg FW tissue)
BCF_{fish}	=	Bioconcentration factor for fish (mg COPC/kg FW tissue)/(mg COPC/kg dissolved water)—unitless
BD	=	Soil bulk density (g soil/cm^3 soil)
Br_{ag}	=	Plant-soil bioconcentration factor for aboveground produce
Br_{forage}	=	Plant-soil bioconcentration factor for forage (µg COPC/g DW plant)/(µg COPC/g soil)—unitless

LIST OF VARIABLES (Continued)

Br_{grain}	=	Plant-soil bioconcentration factor for COPC in grain (µg COPC/g DW plant)/(µg COPC/g soil)—unitless
$Br_{rootveg}$	=	Plant-soil bioconcentration factor for COPC in belowground produce (µg COPC/g FW plant)/(µg COPC/g soil)—unitless
Bs	=	Soil bioavailability factor (unitless)
$BSAF$	=	Biota-to-sediment accumulation factor (mg COPC/kg lipid tissue)/(mg COPC/kg sediment)—unitless
Bv_{ag}	=	COPC air-to-plant biotransfer factor for aboveground produce (µg COPC/g DW plant)/(µg COPC/g air)—unitless
$Bv_{forage/silage}$	=	Air-to-plant biotransfer factor for forage and silage (µg COPC/g DW plant)/(µg COPC/g air)—unitless
C	=	USLE cover management factor (unitless)
C_a	=	Total COPC air concentration (µg/m^3)
C_{acute}	=	Acute air concentration (µg/m^3)
$Cancer\ Risk_i$	=	Individual lifetime risk through indirect exposure to COPC carcinogen *i* (unitless)
$Cancer\ Risk_{inh(i)}$	=	Individual lifetime cancer risk through direct inhalation of COPC carcinogen *i* (unitless)
C_{BS}	=	Bed sediment concentration (or sediment bulk density) (g sediment/cm^3 water)
C_{gen}	=	Generic chemical concentration (mg COPC/kg tissue or media) or (mg/L)
Ccn_k	=	Stack concentration of non-Table A-1 list *i*th carcinogenic COPCs (carbon basis) (mg COPC/m^3 stack emissions)
Ccp_i	=	Stack concentration of Table A-1 list *i*th carcinogenic COPCs (carbon basis) (mg COPC/m^3 stack emissions)
C_d	=	Drag coefficient (unitless)
C_{dw}	=	Dissolved phase water concentration (mg COPC/L water)
C_{fish}	=	Concentration of COPC in fish (mg COPC/kg FW tissue)
C_i	=	Stack concentration *i*th identified COPC (carbon basis) (mg/m^3)
Cn_j	=	Stack concentration of non-carcinogenic COPC *j* (carbon basis) (mg/m^3)
CR	=	Generic contact rate (kg/day or L/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
C_{sb}	=	Concentration sorbed to bed sediment (mg COPC/kg sediment)
Cs_{tD}	=	Soil concentration at time *tD* (mg COPC/kg soil)
C_{TOC}	=	Stack concentration of TOC, including speciated and unspeciated compounds (mg COPC/m^3 stack emissions)
C_{va}	=	Gas phase air concentration (µg COPC/m^3 air)
C_{VOC}	=	Total stack concentration of volatile speciated COPCs with boiling points less than 100°C (mg COPC/m^3 stack emissions)
$C_{VOC}(i)$	=	Stack concentration of the *i*th volatile speciated COPC with a boiling point less than 100°C (carbon basis) (mg COPC/m^3 stack emissions)
C_{wctot}	=	Total COPC concentration in water column (mg COPC/L water column)
C_{wtot}	=	Total water body COPC concentration including water column and bed sediment (g COPC/m^3 water body) or (mg/L)

LIST OF VARIABLES (Continued)

Cyp	=	Unitized yearly average air concentration from particle phase (μg-s/g-m^3)
Cyv	=	Unitized yearly average air concentration from vapor phase (μg-s/g-m^3)
Cywv	=	Unitized yearly (water body and watershed) average air concentration from vapor phase (μg-s/g-m^3)
D_a	=	Diffusivity of COPC in air (cm^2/s)
d_{bs}	=	Depth of upper benthic sediment layer (m)
D_{mean}	=	Mean particle size density for a particular filter cut size
Ds	=	Deposition term (mg COPC/kg soil-yr)
d_{wc}	=	Depth of water column (m)
D_w	=	Diffusivity of COPC in water (cm^2/s)
Dydp	=	Unitized yearly average dry deposition from particle phase (s/m^2-yr)
Dytwp	=	Unitized yearly (water body or watershed) average total (wet and dry) deposition from particle phase (s/m^2-yr)
Dywp	=	Unitized yearly average wet deposition from particle phase (s/m^2-yr)
Dywv	=	Unitized yearly average wet deposition from vapor phase (s/m^2-yr)
Dywwv	=	Unitized yearly (water body and watershed) average wet deposition from vapor phase (s/m^2-yr)
d_z	=	Total water body depth (m)
ED	=	Exposure duration (yr)
EF	=	Exposure frequency (days/yr)
ER	=	Soil enrichment ratio (unitless)
E_v	=	Average annual evapotranspiration (cm/yr)
f_{bs}	=	Fraction of total water body COPC concentration in benthic sediment (unitless)
Fd	=	Fraction of diet that is soil (unitless)
F_i	=	Fraction of plant type *i* grown on contaminated soil and eaten by the animal (unitless)
f_{lipid}	=	Fish lipid content (unitless)
Fw	=	Fraction of COPC wet deposition that adheres to plant surfaces (unitless)
f_{wc}	=	Fraction of total water body COPC concentration in the water column (unitless)
F_v	=	Fraction of COPC air concentration in vapor phase (unitless)
GEF	=	Applicable emission factor for sources with screening values >10,000 ppmv (kg/hr-source)
H	=	Henry's Law constant (atm-m^3/mol)
HI	=	Hazard index (unitless)
HI_j	=	Hazard index for exposure pathway *j* (unitless)
HQ	=	Hazard quotient (unitless)
HQ_i	=	Hazard quotient for COPC *i* (unitless)
$HQ_{inh(i)}$	=	Hazard quotient for direct inhalation of COPC *i* (unitless)

LIST OF VARIABLES (Continued)

I	=	Average annual irrigation (cm/yr)
I_i	=	Daily intake of COPC (*i*) from animal tissue *j* (mg/day)
k	=	von Karman's constant (unitless)
K	=	USLE erodibility factor (ton/acre)
k_b	=	Benthic burial rate constant (yr^{-1})
Kd_{bs}	=	Bed sediment/sediment pore water partition coefficient (cm^3 water/g bottom sediment)
Kd_{ij}	=	Partition coefficient for COPC *i* associated with sorbing material *j* (unitless)
Kd_s	=	Soil-water partition coefficient (cm^3 water/g soil)
Kd_{sw}	=	Suspended sediments/surface water partition coefficient (L water/kg suspended sediment)
K_G	=	Gas phase transfer coefficient (m/yr)
K_L	=	Liquid phase transfer coefficient (m/yr)
K_{oc}	=	Soil organic carbon-water partition coefficient (mL water/g soil)
K_{ocj}	=	Sorbing material-independent organic carbon partition coefficient for COPC *j*
K_{ow}	=	Octanol-water partition coefficient (mg COPC/L octanol)/(mg COPC/L octanol)—unitless
kp	=	Plant surface loss coefficient (yr^{-1})
ks	=	COPC soil loss constant due to all processes (yr^{-1})
kse	=	COPC loss constant due to soil erosion (yr^{-1})
ksg	=	COPC loss constant due to biotic and abiotic degradation (yr^{-1})
ksl	=	COPC loss constant due to leaching (yr^{-1})
ksr	=	COPC loss constant due to surface runoff (yr^{-1})
ksv	=	COPC loss constant due to volatilization (yr^{-1})
k_v	=	Water column volatilization rate constant (yr^{-1})
K_v	=	Overall COPC transfer rate coefficient (m/yr)
k_{wt}	=	Overall total water body dissipation rate constant (yr^{-1})
L	=	Monin-Obukhov Length (m)
$LADD$	=	Lifetime average daily dose (mg COPC/kg BW-day)
L_{DEP}	=	Total (wet and dry) particle phase and wet vapor phase COPC direct deposition load to water body (g/yr)
L_{dif}	=	Vapor phase COPC diffusion (dry deposition) load to water body (g/yr)
leak rate	=	Emission rate from the individual item of equipment (kg/hr)
L_E	=	Soil erosion load (g/yr)
LEF	=	Applicable emission factor for sources with screening values <10,000 ppmv (kg/hr-source)
L_R	=	Runoff load from pervious surfaces (g/yr)
L_{RI}	=	Runoff load from impervious surfaces (g/yr)
L_T	=	Total COPC load to the water body including deposition, runoff, and erosion (g/yr)
LS	=	USLE length-slope factor (unitless)

LIST OF VARIABLES (Continued)

M_{skin}	=	Mass of a thin (skin) layer of below ground vegetable (g)
$M_{vegetable}$	=	Mass of the entire vegetable (g)
MF	=	Metabolism factor (unitless)
n	=	Number of items of equipment of the applicable type in the stream (unitless)
N_{ge}	=	Equipment count (specific equipment type) for sources with screening values >10,000 ppmv
N_{le}	=	Equipment count (specific equipment type) for sources with screening values <10,000 ppmv
OC_i	=	Organic carbon content of sorbing material *i* (unitless)
OC_{sed}	=	Fraction of organic carbon in bottom sediment (unitless)
p°_L	=	Liquid phase vapor pressure of chemical (atm)
p°_S	=	Solid phase vapor pressure of chemical (atm)
P	=	Average annual precipitation (cm/yr)
PF	=	USLE supporting practice factor (unitless)
Pd	=	Aboveground exposed produce concentration due to direct (wet and dry) deposition onto plant surfaces (mg COPC/kg DW)
P_i	=	Total COPC concentration in plant type *i* ingested by the animal (mg/kg DW)
Pr	=	Aboveground exposed and protected produce concentration due to root uptake (mg COPC/kg DW)
Pr_{bg}	=	Belowground produce concentration due to root uptake (mg COPC/kg DW)
Pv	=	Concentration of COPC in plant due to air-to-plant transfer (mg COPC/kg DW)
Q	=	COPC emission rate (g/s)
Q_i	=	Emission rate of COPC *(i)* (g/s)
$Q_{i(adj)}$	=	Adjusted emission rate of COPC *(i)* (g/s)
$Qcp_{i(adj)}$	=	Adjusted emission rate of Table A-1 carcinogenic COPC *(i)* (g/s)
Qcp_i	=	Emission rate of Table A-1 carcinogenic COPC *(i)* (g/s)
Q_f	=	Anthropogenic heat flux (W/m^2)
Qp_i	=	Quantity of plant type *i* ingested by the animal each day (kg DW/day)
Qs	=	Quantity of soil ingested by the animal each day (kg/day)
$Q_{VOCi,adj}$	=	Adjusted emission rate of the *i*th volatile speciated COPC with a boiling point less than 100°C (g/s)
Q_{VOCi}	=	Emission rate of the *i*th volatile speciated COPC (g/s)
Q_*	=	Net radiation absorbed (W/m^2)
r	=	Interception fraction—the fraction of material in rain intercepted by vegetation and initially retained (unitless)
R	=	Universal gas constant ($atm\text{-}m^3/mol\text{-}K$)

LIST OF VARIABLES (Continued)

RCF	=	Root concentration factor (μg COPC/g DW plant)/(μg COPC/ml soil water)
RO	=	Average annual surface runoff from pervious surfaces (cm/yr)
REL	=	California EPA Air Toxics Hot Spots Program acute reference exposure levels
RF	=	USLE rainfall (or erosivity) factor (yr^{-1})
Rp	=	Interception fraction of the edible portion of plant (unitless)
SBCF	=	Scale bias correction factor (unitless)
SD	=	Sediment delivery ratio (unitless)
ΔSf	=	Entropy of fusion [$\Delta S_f/R$ = 6.79 (unitless)]
SF	=	Slope factor $(mg/kg\text{-}day)^{-1}$
S_T	=	Whitby's average surface area of particulates (aerosols) = 3.5×10^{-6} cm^2/cm^3 air for background plus local sources = 1.1×10^{-5} cm^2/cm^3 air for urban sources
SV	=	Screening value (ppmv)
T_a	=	Ambient air temperature (K)
T_1	=	Time period at the beginning of combustion (yr)
T_2	=	Length of exposure duration (yr)
tD	=	Time period over which deposition occurs (time period of combustion) (yr)
T_m	=	Melting point of chemical (K)
TOC_{VOC}	=	Stack concentration of volatile TOC, including speciated and unspeciated compounds (mg/m^3)
TOC_{CSV}	=	Stack concentration of CSV TOC, including speciated and unspeciated compounds (mg/m^3)
TOC_{GRAV}	=	Stack concentration of GRAV TOC, including speciated and unspeciated compounds (mg/m^3)
Tp	=	Length of plant exposure to deposition per harvest of edible portion of plant (yr)
tp_i	=	Length of plant's exposure to deposition per harvest of the edible portion of the *i* th plant group (yr)
Total Cancer Risk	=	Individual lifetime cancer risk through indirect exposure to all COPC carcinogens (unitless)
$Total\ Cancer\ Risk_{inh}$	=	Total individual lifetime cancer risk through direct inhalation of all COPC carcinogens
TSS	=	Total suspended solids concentration (mg/L)
T_{wk}	=	Water body temperature (K)
$t_{1/2}$	=	Half-time of COPC (days)
u	=	Current velocity (m/s)
Vdv	=	Dry deposition velocity (cm/s)
Vf_x	=	Average volumetric flow rate through water body (m^3/yr)

LIST OF VARIABLES (Continued)

VG_{ag}	=	Empirical correction factor for aboveground produce (forage and silage)(unitless)
$VG_{rootveg}$	=	Empirical correction factor for below ground produce (unitless)
VOC	=	Total VOC emission rate for an equipment type (kg/hr)
VOC_s	=	VOC emission rate from all equipment in the stream of a given equipment type (kg/hr)
Vp	=	Vapor pressure of COPC (atm)
W	=	Average annual wind speed (m/s)
w_b	=	Rate of burial (m/yr)
WF_{VOC}	=	Average weight fraction of VOC in the stream (unitless)
X_e	=	Unit soil loss (kg/m^2-yr)
Yh	=	Dry harvest yield = 1.22×10^{11} kg DW, calculated from the 1993 U.S. average wet weight *Yh* of 1.35×10^{11} kg (USDA 1994b) and a conversion factor of 0.9 (Fries 1994)
Yh_i	=	Harvest yield of *i*th crop (kg DW)
Yp	=	Yield or standing crop biomass of edible portion of plant (productivity) (kg DW/m^2)
Yp_i	=	Yield or standing crop biomass of the edible portion of the plant (productivity) (kg DW/m^2)
Z_s	=	Soil mixing zone depth (cm)
0.01	=	Units conversion factor (kg $cm^2/mg\text{-}m^2$)
10^{-6}	=	Units conversion factor (g/µg)
10^{-6}	=	Units conversion factor (kg/mg)
0.31536	=	Units conversion factor (m-g-s/cm-µg-yr)
365	=	Units conversion factor (days/yr)
907.18	=	Units conversion factor (kg/ton)
0.1	=	Units conversion factor ($g\text{-}kg/cm^2\text{-}m^2$)
0.001	=	Units conversion factor ($kg\text{-}cm^2/mg\text{-}m^2$)
100	=	Units conversion factor ($mg\text{-}cm^2/kg\text{-}cm^2$)
1000	=	Units conversion factor (mg/g)
4047	=	Units conversion factor (m^2/acre)
1×10^3	=	Units conversion factor (g/kg)
3.1536×10^7	=	Units conversion factor (s/yr)

Chapter 1
Introduction

What's Covered in Chapter 1:

- ♦ Objective and Purpose
- ♦ Related Trial Burn Issues
- ♦ Reference Documents
- ♦ Document Organization

Risk assessment is a science used to evaluate the carcinogenic risks and noncarcinogenic hazards to human health that are attributable to emissions from hazardous waste combustion units. These risk assessments include the evaluation of both direct and indirect risks. There is sufficient guidance available regarding the performance of direct inhalation risk assessments. On the other hand, indirect risk assessments are newer and more complex. As a result, this document describes the evaluation of direct inhalation risk, but primarily focuses on the procedures used to estimate risk resulting from indirect pathways. The following definitions as adopted from the National Academy of Sciences 1983, *Risk Assessment in the Federal Government*, for use throughout this guidance:

Risk Assessment	The scientific evaluation of potential health impacts that may result from exposure to a particular substance or mixture of substances under specified conditions.
Hazard	An impact to human health by chemicals of potential concern.
Risk	An estimation of the probability that an adverse health impact may occur as a result of exposure to chemicals in the amount and by the pathways identified.
Dose	Defined as one oral exposure.
Exposure	Exposure to chemicals by relevant pathways to identified receptors.
Indirect Exposure	Resulting from contact of human and ecological receptors with soil, plants, or waterbodies on which emitted chemical has been deposited. For screening level purposes, indirect exposure include ingestion of above ground fruits and vegetables, beef and milk, freshwater fish and soil.

Direct Exposure Exposure via inhalation.

This Human Health Risk Assessment Protocol (HHRAP) has been developed as national guidance to consolidate information presented in other risk assessment guidance and methodology documents previously prepared by U.S. EPA and state environmental agencies. In addition, the HHRAP also addresses issues that have been identified while conducting risk assessments for existing hazardous waste combustion units. The overall purpose of this document is to explain how risk assessments should be performed at hazardous waste combustion facilities. This document is intended as (1) guidance for personnel conducting risk assessments, and (2) an information resource for permit writers, risk managers, and community relations personnel.

In the April 19, 1996, preamble to the proposed MACT rule, U.S. EPA recommended that site-specific risk assessments be conducted as part of the RCRA permitting process for hazardous waste combustors as necessary to protect human health and the environment. Often, the determination of whether or not a permit is sufficiently protective can be based on its conformance to the applicable technical standards specified in the regulations. Since the time that the current regulations for hazardous waste incinerators and boilers/industrial furnaces were issued (1981 and 1991, respectively), however, information has become available to suggest that these performance standards may not fully address potentially significant risks. Many recent studies (including the *Draft Health Reassessment of Dioxin-Like Compounds*, *Mercury Study Report to Congress*, and *Risk Assessment Support to the Development of Technical Standards for Emissions from Combustion Units Burning Hazardous Wastes: Background Information Document*) indicate that there can be significant risks from indirect exposure pathways (e.g., pathways other than direct inhalation). The food chain pathway appears to be particularly important for bioaccumulative pollutants which may be emitted from hazardous waste combustion units. In many cases, risks from indirect exposure may constitute the majority of the risk from a hazardous waste combustor. This key portion of the risk from hazardous waste combustor emissions was not directly taken into account when the hazardous waste combustion standards were developed. In addition, uncertainty remains regarding the types and quantities of non-dioxin products of incomplete combustion emitted from combustion units and the risks posed by these compounds.

The RCRA "omnibus" authority of §3005(c)(3) of RCRA, 42 U.S.C. §6925(c)(3) and 40 CFR. §270.32(b)(2) gives the Agency both the authority and the responsibility to establish permit conditions on a case-by-case basis as necessary to protect human health and the environment. Performance of a site-specific risk assessment can provide the information necessary to determine what, if any, additional permit conditions are necessary for each situation to ensure that operation of the combustion unit is protective of human health and the environment. Under 40 C.F.R. §270.10(k), U.S. EPA may require a permit applicant to submit additional information (e.g., a site-specific risk assessment) that the Agency needs to establish permit conditions under the omnibus authority. In certain cases, the Agency may also seek additional testing or data under the authority of RCRA §3013 (where the presence or release of a hazardous waste “may present a substantial hazard to human health or the environment”) and may issue an order requiring the facility to conduct monitoring, testing, analysis, and reporting. Any decision to add permit conditions based on a site-specific risk assessment under this authority must be justified in the administrative record for each facility, and the implementing agency should explain the basis for the conditions.

The permitting agency should consider several factors in its evaluation of the need to perform a risk assessment (human health and ecological). These factors include:

- whether any proposed or final regulatory standards exist that U.S. EPA has shown to be protective for site-specific receptors

- whether the facility is exceeding any final technical standards

- the current level of hazardous constituents being emitted by a facility, particularly in comparison to proposed or final technical standards, and to levels at other facilities where risks have been estimated

- the scope of waste minimization efforts and the status of implementation of a facility waste minimization plan

- particular site-specific considerations related to the exposure setting (such as physical, land use, and sensitive subpopulation characteristics) and the impact of these characteristics on potential risks

- the hazardous constituents most likely to be found and those most likely to pose significant risk

- the volume and types of wastes being burned

- the level of public interest and community involvement attributable to the facility

This list is by no means exhaustive, but is meant only to suggest significant factors that have thus far been identified. Others may be equally or more important.

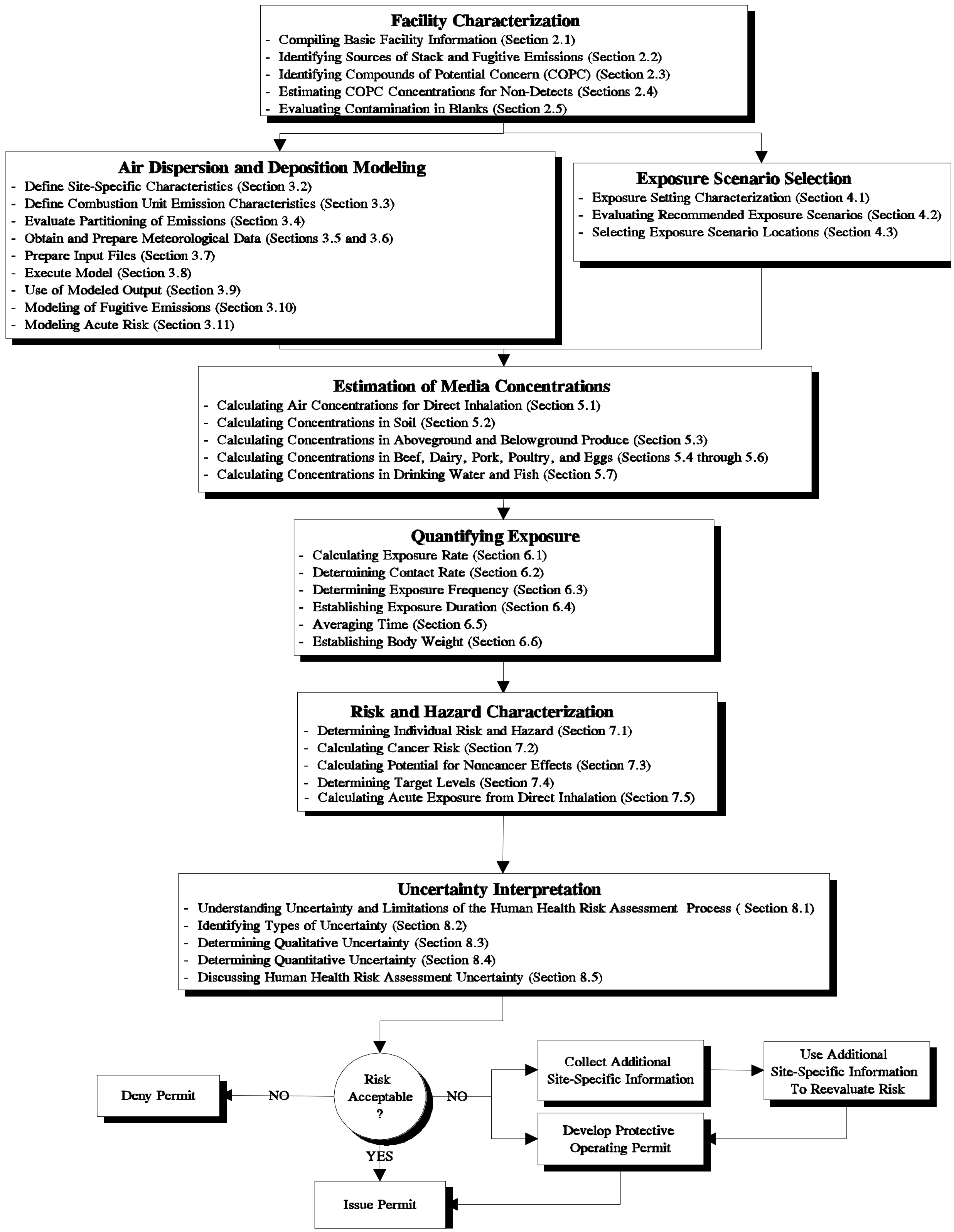
The companion document of the HHRAP is the Screening Level Ecological Risk Assessment Protocol (SLERAP). U.S. EPA OSW has prepared these guidance documents as a resource to be used by authorized agencies developing risk assessment reports to support permitting decisions for hazardous waste combustion units.

1.1 OBJECTIVE AND PURPOSE

U.S. EPA OSW's objective is to present a user-friendly set of procedures for performing risk assessments, including (1) a complete explanation of the basis of those procedures, and (2) a comprehensive source of data needed to complete those procedures. The first volume of this document provides the explanation (Chapters 1 through 9); and the second volume (Appendixes A-B) provides the data sources. Appendix A presents compound-specific information necessary to complete the risk assessment. Appendixes B and C present a user-friendly set of procedures for performing risk assessments. Figure 1-1 summarizes the tasks needed to complete a risk assessment and refers the reader to chapters in this guidance in which each task is described.

Implementation of this guidance will demonstrate that developing defensible estimates of compound emission rates is one of the most important elements of the risk assessment. As described in Chapter 2, traditional trial burns conducted to measure destruction and removal efficiency (DRE) do not sufficiently characterize organic products of incomplete combustion (PIC) and metal emissions for use in performing risk assessments. In some instances, a facility or regulatory agency may want to perform a pretrial burn risk assessment, following the procedures outlined in this document, to ensure that sample collection times during the trial burn or risk assessment burn are sufficient to collect the sample volumes needed to meet the detection limits needed for the risk assessment. The decision to perform such an assessment should consider regulatory permitting schedules and other site-specific factors.

FIGURE 1-1
HUMAN HEALTH RISK ASSESSMENT PROCESS



U.S. EPA OSW anticipates that risk assessments will be completed for new and existing facilities as part of the permit application process. The HHRAP recommends a process for evaluating *reasonable*—not theoretical worst-case maximum—potential risks to receptors posed by emissions from RCRA regulated units. The use of existing and site-specific information early in, and throughout, the risk assessment process is encouraged; conservative assumptions should be made only when needed to ensure that emissions from combustion units do not pose unacceptable risks. More conservative assumptions may be incorporated to make the process fit a classical "screening level" approach that is more conservative and may be easier to complete.

Regardless of whether theoretical worst case or more reasonable conservative assumptions are used in completing the risk assessment process, every risk assessment is limited by the quantity and quality of:

- site-specific environmental data
- emission rate information
- other assumptions made during the risk estimation process (for example, fate and transport variables, exposure assumptions, and receptor characteristics)

These limitations and uncertainties are described extensively throughout this document and the appendixes, and are summarized in Chapter 8.

Unacceptable risks or other significant issues identified by collecting preliminary site information and completing risk assessment calculations can be addressed by the permitting process or during an iteration of the risk assessment. After the initial risk assessment has been completed, it may be used by risk managers and permit writers in several ways:

- If the initial risk assessment indicates that estimated cancer risks and noncancer hazards are below regulatory levels of concern, risk managers and permit writers will likely proceed through the permitting process without adding any risk-based unit operating conditions to the permit.
- If the initial risk assessment indicates potentially unacceptable risks, additional site-specific information demonstrated to be more representative of the exposure setting may be collected and additional iterations of risk assessment calculations can then be performed.

- If the initial risk assessment or subsequent iterations indicate potentially unacceptable risks, risk managers and permit writers may use the results of the risk assessment to revise tentative permit conditions (for example, waste feed limitations, process operating conditions, and expanded environmental monitoring). To determine if the subject hazardous waste combustion unit can be operated in a manner that is protective of human health and the environment, an additional iteration of the risk assessment should be completed using the revised tentative operating conditions. If the revised conditions still indicate unacceptable risks, this process can be continued in an iterative fashion until acceptable levels are reached. In some situations, it may be possible to select target risk levels and back-calculate the risk assessment to determine the appropriate emission and waste feed rate levels. In any case, the acceptable waste feed rate and other appropriate conditions can then be incorporated as additional permit conditions.

- If the initial risk assessment, or subsequent iterations, indicate potentially unacceptable risks, risk managers and permit writers may also choose to deny the permit.

This process is also outlined in Figure 1-1. As stated earlier, in some instances, a facility or regulatory agency may want to perform a pretrial burn risk assessment—following the procedures outlined in this document—to ensure that sample collection times during the trial burn or risk assessment burn are sufficient to collect the sample volumes necessary to meet the appropriate detection limits for the risk assessment. This is expected to reduce the need for additional trial burn tests or iterations of the risk assessment due to problems caused when detection limits are not low enough to estimate risk with certainty sufficient for regulatory decision making. For example, if detection limits are too high then estimates of risk based on detection limits may be overly conservative.

1.2 RELATED TRIAL BURN ISSUES

In the course of developing this guidance and completing risk assessments across the country, U.S. EPA OSW has learned that developing defensible estimates of compound of potential concern (COPC) emission rates is one of the most important parts of the risk assessment process. As described in Chapter 2, traditional trial burns conducted to measure destruction and removal efficiency (DRE) *do not* sufficiently characterize organic products of incomplete combustion (PIC) and metal emissions for use in performing risk assessments.

U.S. EPA OSW considers the trial burn and risk assessment planning and implementation processes as interdependent aspects of the hazardous waste combustion unit permitting process. In addition, U.S. EPA

OSW advocates that facility planning, regulatory agency review, and completion of tasks needed for both processes be conducted simultaneously to eliminate redundancy or the need to repeat activities. U.S. EPA OSW expects that the following guidance documents will typically be used as the main sources of information for developing and conducting appropriate trial burns:

- U.S. EPA. 1989f. *Handbook: Guidance on Setting Permit Conditions and Reporting Trial Burn Results. Volume II of the Hazardous Waste Incineration Guidance Series.* Office of Research and Development (ORD). EPA/625/6-89/019. January.

- U.S. EPA. 1989g. *Handbook: Hazardous Waste Incineration Measurement Guidance Manual. Volume III of the Hazardous Waste Incineration Guidance Series.* Office of Solid Waste and Emergency Response (OSWER). EPA/625/6-89/021. June.

- U.S. EPA. 1992c. *Technical Implementation Document for EPA's Boiler and Industrial Furnace Regulations.* OSWER. EPA-530-R-92-011. March.

- U.S. EPA. 1994n. *Draft Revision of Guidance on Trial Burns. Attachment B, Draft Exposure Assessment Guidance for Resource Conservation and Recovery Act (RCRA) Hazardous Waste Combustion Facilities*. OSWER. June 2.

- Generic Trial Burn Plan and QAPPs developed by EPA regional offices or states.

1.3 REFERENCE DOCUMENTS

This section describes, in chronological order, the primary guidance documents used to prepare this HHRAP. Some of the guidance documents received a thorough review from EPA's Science Advisory Board, which mostly supported the work. Additional references used to prepare this HHRAP are listed in the References chapter of this document. These documents have been developed over a period of several years; in most cases, revisions to the original guidance documents address only the specific issues being revised rather than representing a complete revision of the original document. The following discussion lists and briefly describes each document. Overall, each of the guidance documents reflects a continual enhancing of the methodology. The most current risk assessment methodology frequently referenced in this guidance is the U.S. EPA NCEA guidance, *Methodology for Assessing Health Risks Associated with Multiple Exposure Pathways to Combustor Emissions* (In Press).

References, such as "U.S. EPA 1990e," correspond to the citation for the document specified in the Reference section of this guidance.

The following document was the first U.S. EPA guidance document for conducting risk assessments at combustion units:

- U.S. EPA. 1990e. *Interim Final Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Environmental Criteria and Assessment Office. ORD. EPA-600-90-003. January.

This document outlined and explained a set of general procedures for conducting risk assessments. This document was subsequently revised by the following:

- U.S. EPA. 1993h. *Review Draft Addendum to the Methodology for Assessing Health Risks Associated with Indirect Exposure to Combustor Emissions*. Office of Health and Environmental Assessment. ORD. EPA-600-AP-93-003. November 10.

This document outlined recommended revisions to previous U.S. EPA guidance (1990e), which have been used by the risk assessment community since the release of the document; however, these recommended revisions were never formally incorporated into the original document. In 1994, U.S. EPA issued several additional risk assessment documents, including the following:

- U.S. EPA. 1994f. *Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. OSWER. EPA-530-R-94-021. April.

The actual substance of the 1994 U.S. EPA guidance (1994f) is included in the following series of attachments, all issued as separate documents:

- U.S. EPA. 1994g. *Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

- U.S. EPA. 1994h. Table 1, "Chemicals Recommended for Identification," and Table 2, "Chemicals for Potential Identification." *Attachment A, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 15.

- U.S. EPA. 1994i. *Draft Revision, Implementation Guidance for Conducting Indirect Exposure Analysis at RCRA Combustion Units. Attachment, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. April 22.

- U.S. EPA. 1994j. *Draft Guidance on Trial Burns. Attachment B, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. May 2.

- U.S. EPA. 1998 (In Press). *"Guidance on Collection of Emissions Data to Support Site-Specific Risk Assessments at Hazardous Waste Combustion Facilities*. Internal Review Draft. Prepared by EPA Region 4 and the Office of Solid Waste.

Combined, these four documents present a revised procedure for completing a risk assessment. Because the original U.S. EPA guidance documents (1990e and 1993h) contained much of the background information necessary to complete the risk assessment process, this information was not repeated. In 1994, this new guidance was further revised by the following documents:

- U.S. EPA. 1994n. *Draft Revision of Guidance on Trial Burns. Attachment B, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. OSWER. June 2.

- U.S. EPA. 1994p. *Errata, Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. October 4.

- U.S. EPA. 1994r. *Revised Draft Guidance for Performing Screening Level Risk Analyses at Combustion Facilities Burning Hazardous Wastes. Attachment C, Draft Exposure Assessment Guidance for RCRA Hazardous Waste Combustion Facilities*. Office of Emergency and Remedial Response. OSW. December 14.

More recently, NC DEHNR developed the following guidance document for conducting risk assessments:

- NC DEHNR. 1997. *North Carolina Protocol for Performing Indirect Exposure Risk Assessments for Hazardous Waste Combustion Units*. January.

The NC DEHNR document reiterates U.S. EPA procedures (1994r), with the addition of a tiered approach that allows the regulatory agency or facility to choose the investment they want to make in conducting risk assessments. For instance, a small, on-site unit with limited waste stream variability is allowed the opportunity to conduct a Tier 1 assessment (more worst-case), whereas a larger facility with a diverse waste feed mixture may decide to complete a Tier 2 or 3 assessment (progressively more site-specific).

Finally, U.S. EPA OSW contracted for the development of *The Background Information Document to the Risk Assessment Support to the Development of Technical Standards for Emissions from Combustion*

Units Burning Hazardous Wastes (Research Triangle Institute 1996) to support the proposed Hazardous Waste Combustion Rule. This document was reviewed and considered throughout the development of the HHRAP in order to ensure that the approach outlined is consistent with the most current OSW risk assessment policy.